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A preliminary study of 8 in. soil temperatures under two non-identical exposures

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Introduction

Regularly over the years - in extreme cases thrice at a single station - observers report the fracture of 8 inch soil thermometers. Apart from damage by birds etc., it is assumed that fracture could arise from frost heaving and/or horizontal shearing due to frost in many types of soil - notably, of course, those with a high clay fraction.

Apart from the immediate objective of the tests, the actual data collected dealing with point to point variability of soil temperatures are of wider interest and are the justification for this current note.

In an attempt to reduce damage to thermometers, trials have been initiated in which a "cylinder" of the native soil, $1\frac{1}{2}$ inch to 2 inches diameter has been removed with an auger, a glass tube of about the same diameter, inserted to 8 in. depth, to form a lining, the thermometer placed centrally in the tube and the hole then filled with a coarse sand; this is gently, but firmly, tapped down so forming a "plug" of sand in the native soil. This is described as a "medium loam". Certainly there are other soils likely to be encountered with a much higher clay fraction. The expectation is that any frost-induced movement in the sand will be much less than in any natural soil and that the risk of fracture of the instrument will be reduced.

The first stage in the trial is a straight comparison of the 09h readings of the 8 in. soil thermometer between the standard instrument and the "trial" installation. As a guide to the point-to-point variability of 8 in. soil temperature under standard conditions, we have the result obtained by Smith (1951) who examined point-to-point variability of standard climatological measurement at Kew throughout 1949. To date, readings of the 09h soil temperature are available from E Craigs for 135 days during the period February to June 1970; Smith's corresponding results (1157 obs), apply to the whole of 1949. Smith used four replicates and assumed the "true" value to be the mean of the four and the difference between individual readings at a given time and the mean provided the population of errors. In the current work the "error" is merely the difference between the readings of the "trial" and of the standard instrument.

Data

In Table 1 are given the frequency distributions of errors in the two series (Note that, of necessity the mean value in Smith's series is zero).

Table 1: Percentage Frequency Distribution of Errors

Errors (°F)	-1.0	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	
E Craigs	0.7	3.0	2.2	0.7	4.4	4.4	9.6	5.9	19.3	23.0	
Kew	0.1	0.0	0.0	0.3	0.5	0.9	2.6	4.5	8.5	18.6	
Errors (°F)	0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9	+1.0
E Craigs	14.8	1.5	3.7	0.8	0.7	0.7	2.2	0	1.5	0.7	0.0
Kew	25.6	21.3	9.7	4.5	0.9	0.8	0.6	0.4	0.1	0.1	0.0

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Statistical parameters for the distribution are given below (Table 2)

Table 2: Some Statistical Parameters for the two series

	Mean	Mean Deviation	s.d.	Range/s.d.	% obs within ± s.d.	% obs within ± s.d.
E Craigs	-0.17	0.28	0.33	5.75	76	90
Kew	0	0.14	0.20	9.5	83.7	96.2

From Tables 1 and 2 we note:

(i) At E Craigs on average the temperature in the test (sand) site is 0.17°F below the standard. The distribution is positively skewed. 76% of observations lie within + one standard deviation (cf with 68.2 for a Gaussian distribution) but only 90% within ± 2 x standard deviation.

(ii) At Kew nearly 84% lies within ± one standard deviation.

(iii) In both cases the distribution clusters around their respective means more closely than for a Gaussian one (i.e. both are more leptokurtic).

(iv) On the assumption that the Kew values give a valid point-to-point variance over a homogeneous site, the standard deviation due to the different modes of exposure at E Craigs may provisionally be stated as ± .26.

As will be evident from Table 3 there appears to be some variation in behaviour from month to month, particularly in relation to spread.

Table 3: Frequency distribution of errors by month: with monthly rainfall and rain days

	Errors									Monthly	
Month	0.8-1.0	0.6-0.7	0.4-0.5	0.2-0.3	-0.1-+0.1	-0.2--0.3	-0.4--0.5	-0.6--0.7	-0.8--1.0	Rain-fall	Rain Days
Feb (a)				1	8	0	4	1		1.41	6
March		1	0	1	14	8	3	2	2	0.63	14
April	2			1	9	9	4	3	2	1.64	15
May	2	2	2	2	11	7	3	0	2	1.09	8
June				1	11	10	5	1	2	1.69	9

(a) 15th to 28th only.

Some additional comments

The data were scrutinised to see if there was any clear connection between the magnitude of an "error" and the associated weather (Table 4).

Table 4: Errors against rainfall of previous 24 hours

(Rainfall in ins)

Error (^{o}F)	Nil	Trace	0.01-0.05	0.06-0.10	0.11-0.15	0.16-0.20	0.21-0.25	0.26-0.30	0.31-0.35	0.36-0.40	0.41-0.45	0.46-0.50	≥ 0.51
+1.0													
+0.9	1												
+0.8	2												
+0.7													
+0.6	2	1											
+0.5	1												
+0.4	1												
+0.3		1											
+0.2	5												
+0.1	3												
0	8	6	2	0	2	1	1					1	
-0.1	13	5	5	3	1	2							1*
-0.2	11	3	7	1	1	1						1	
-0.3	6	0	1	0	2								
-0.4	4	0	3	1	1	0	1	2					
-0.5	2	0	3						1				
-0.6	2	1	1	1					1				
-0.7	1												
-0.8	3												
-0.9	2	1	1										
-1.0	1												

(* 0.71 - 0.75)

The only relationship which seems to be appearing so far is one between the range of error and the 24 hour rainfall prior to the reading. Large errors (both positive and negative) are associated with no rain. With the 24 hour fall $\geq$ 0.10 in. the range of error is sharply reduced and the magnitude of errors is small - with but two exceptions - when the 24 hour fall $\geq$ 0.25 in.

As to any connection between the size of the error and the absolute of temperature all that can so far be said is that large negative errors (i.e. cases in which the experimental treatment gave considerably lower temperatures than the standard) did not occur when the temperature fell below about 40°F.

REFERENCES

Smith L P (1951) "Random errors in standard observations". London, Met Mag 80 1951 p236.

(Full details are available in an unpublished note held in the Meteorological Office).